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THE SHORE PLATFORMS OF FLINDERS, VICTORIA

by J. T. Jutson, D.Sc., LL.B.

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Abstract

Along the shores of Western Port Bay and of the ocean, the rocks consist of alternating slightly undulating bands of Cainozoic basic lava flows and pyroclastic rocks (tuffs and agglomerates) and a red clay of uncertain origin varying in thickness from a foot or less to about 40 feet. In the bay, the coast-line is mature and consists of a series of long, open, sandy bays or scallops, flanked by comparatively low headlands and backed by steeply sloping cliffs, which are mainly covered by vegetation. The ocean coast-line is youthful and is in marked contrast with that of the bay in that it consists of a succession of comparatively small bays, flanked by high steep headlands, resulting locally in a crenulated outline and with more bare rocks exposed in the cliff sections. Along both coasts there are extensive well-developed shore platforms, those of the bay being wider than those of the ocean.

The platforms are of three types: (1) the high-level; (2) the normal; and (3) the ultimate. Above the high-level platforms are narrow shelves which up to a height of at least 10 feet above the normal platform (which is usually only fully exposed at low tide) are being cut by the waves and spray of the sea assisted by atmospheric erosion. Rock fans due to marine erosion are other features associated with the platforms.

The platforms and associated features are due in the main to wave planation and the working of the sea downward along the nearly vertical joints of the hard basalt. Practically no ramparts exist at the outer (seaward) edge of the normal platform, but the abrasion ramp at the inner (landward) edge is almost invariably present. All the platforms except the ultimate one are in process of destruction at their seaward edges and most are in process of extension at their landward edges. The actual surfaces of the platforms are being modified in various ways.

The platforms and shelves afford no definite evidence of recent change of sea-level.

Contents

Introduction

Flinders, at the south-eastern corner of the Mornington Peninsula and at the south-western corner of Western Port Bay, has an extensive series of shore platforms, both in the bay and along the ocean front. A study of these features

throws considerable light on their mode of formation, growth and destruction as well as on the erosive processes of the sea in general.

The observations recorded in this paper are based on that portion of the ocean coast which extends westwards from West Head for about five miles to just beyond Stockyard Creek and on that portion of the bay coast which extends northwards from the same headland for about eight miles to Coles' Beach (Fig. 1).

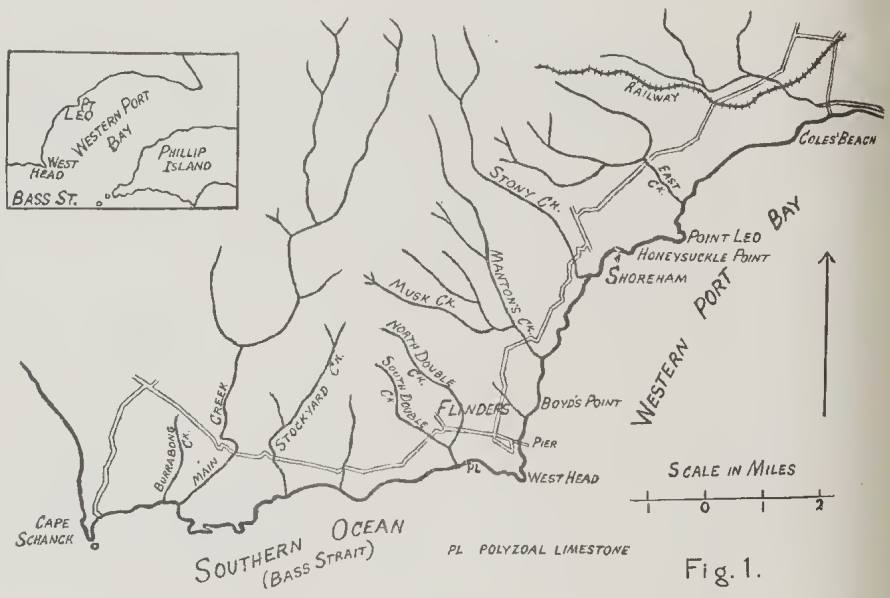


Fig. 1. Outline map of the Flinders District.

Previous Work

So far as the writer is aware, with the exception of remarks by J. A. Kershaw (1902), A. E. Kitson (1902) and S. R. Mitchell (1930) as to the occurrence of rock platforms at Flinders due to marine erosion, there is no literature dealing with the geomorphology of the platforms. The general geology, however, was indicated many years ago by A. R. C. Selwyn (1856) in his valuable map accompanying his report on the Mornington Peninsula and the country farther north. G. B. Pritchard (1903) and A. E. Kitson (1902) have also made some contributions to the geology of the area. These various records have been availed of by the writer so far as the study of the geology is required for the purpose of this paper. T. S. Hall (1902) suggested that there had been a recent emergence to the extent of at least five feet and R. A. Keble (1936) has discussed the question of advancing and retreating shorelines on the western coast of Western Port Bay.

The Component Rocks

The rocks forming the coast consist almost entirely of basalt and associated pryoclastic rocks (agglomerates, breccias and tuffs) of Cainozoic age. There is also a red clay, the origin of which is not clear. It is out of all these rocks that the shore platforms have been carved. Further details are given in the discussion as to the origin of the platforms.

On top of the volcanic rocks there are some Tertiary or Post-Tertiary sands

but these do not bear on the subject matter of this paper so they are not further mentioned.

The Coast-Line

The ocean coast-line is an irregular one, consisting of bold headlands separated by pronounced bays (Plate V, Fig. 1). This is true, broadly speaking, but in detail the coast-line is minutely crenulated. The headlands are simple or compound, the simple form having only one prominent point and the compound form having two or more minor points, separated by tiny bays. The headlands in their lower portions are usually vertical with bare rock surfaces up to about 25 feet above sea-level, but are clothed with vegetation in their upper less steep portions. The cliffs backing the bays mostly have vegetation from summit to or nearly to base, and their angle of slope would probably average about 70° from the horizontal. A factor in keeping the cliffs steep is the alternation of hard and soft rocks. The latter, when underlying the former, are fairly rapidly eroded and so falls of the upper hard bands take place. The same alternation at sea-level is, in places, responsible for the headlands and the bays.

Most of the bays have scanty sandy beaches, but shingle beaches are common, especially on each side of a headland. Extensive, but comparatively narrow, rock platforms occur, particularly in front of the headlands. The coast-line is youthful or early mature. At the prominent headland on the ocean about a mile to the east of the mouth of Stockyard Creek there is a remarkable scree deposit.

The bay coast-line is smoother in outline than that of the ocean. The headlands are low and narrow with vertical rock faces usually rising only a few feet above sea-level, beyond which are sloping vegetated cliffs. With the exceptions of Point Leo and at Coles' Beach, the headlands project very slightly beyond the bays which form the major portion of the coast-line. The bays are backed by wide sandy beaches—a fine example of which is between Points Honeysuckle and Leo—with some shingle, especially near the headlands, and by fairly steep cliffs mostly covered from top to base or near the base by vegetation. Long and wide well-developed rock platforms are characteristic of the bay coast. The coast-line is mature.

In the ocean, as well as in Western Port Bay, the vegetated cliffs are covered by a mantle of detritus. In the bays, those cliffs in many places are in course of erosion by the sea, thus producing vertical cliffs of solid rock or detritus for a height of from two to 20 feet or more above sea level. At the ocean, the cliffs are from 100 to 200 feet high and those of the bay from 50 to 100 feet.

The shingle in both ocean and bay consists only of hard grey basalt, well waterworn, the individual pebbles or boulders varying in diameter from one to nine or ten inches. The boulders of some heavy shingle bands are sub-angular and have been derived from near-by columnar basalt. The shingle occurs mainly at the foot of the cliffs, apart from the fronts of the headlands which are mostly free of shingle, and is thrown to a height of five feet above the level of the normal platform. In places, as at Double Creek on the ocean, it blocks the mouth of a stream, but the water filters through. Shingle is also found on some platforms as is noted when treating of those features.

Progradation is mostly absent along the ocean coast, except in front of the polyzoal limestone outcrop, but within the bay there are areas up to about two chains wide, consisting of sand or shingle or both, now wholly or partly covered with vegetation, probably nowhere more than three feet above the beaches, and forming either level belts or a series of low beach ridges with intervening depressions. The level belts may originally also have been ridges and depressions, but, by the filling in of the latter by marine detritus, those

features have been transformed into level belts. Examples are found immediately to the south of the pier ; to the north of Boyd's Point ; just to the north of Shoreham ; and at Coles' Beach, all in Western Port Bay. These prograded areas, which in places are capped by blown sands, are being eroded again so that cliffs of sand up to eight feet high are fairly common. At Point Leo, the erosion is bringing down large trees.

The country immediately behind the coast-line is fairly well dissected by small valleys, some of which are hanging, an example of which is to the east of Stockyard Creek where the stream, after descending for a short distance in cascades, has a vertical drop to the beach of about 50 feet.

The range of the tide at the Flinders Pier, which is just inside Western Port Bay from the ocean, is nine feet for spring and seven feet for neap tides. This information has been kindly supplied by the Ports and Harbours Branch of the Public Works Department of Victoria. These are the only records available as to the range of the tide along the portions of the ocean and bay coast-line dealt with in this paper. Probably at the actual ocean front the range will not be less, and may be greater. It may diminish northwards from the pier.

General Description of the Platforms

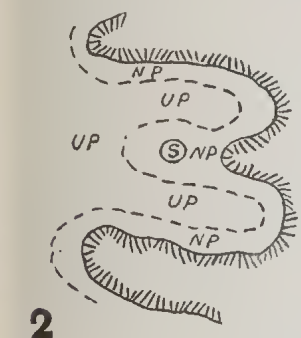
These consist of the normal platform, the high-level platforms (with their associated shelves) and the ultimate platform. In addition there are rock fans and resurrected platforms. The nomenclature adopted is that used by the writer in his descriptions of the platforms at Sydney, New South Wales (1939), and at Mt. Martha Port Phillip Bay, Victoria (1940). It is recognised that the terms used in this paper are not the most suitable, but in the absence of better ones they are retained for the present. The terms " upper horizontal platform " and ' lower sloping platform ' in replacement of ' normal platform ' and ' ultimate platform ' respectively are from the descriptive aspect more suitable but they are clumsy and therefore are rejected.

The Normal Platform

General Features. The normal platform is exposed at low tide and is generally covered at high tide. It is very extensively developed along the coasts of the ocean and of Western Port Bay. In the latter, fine examples are at West Head, Boyd's Point, Shoreham, Honeysuckle Point, Point Leo and Coles' Beach (Plate V, Fig. 3). At the ocean it extends, broadly speaking, almost continuously westward from West Head (Plate VI, Fig. 1). In places it has been much cut into by marine erosion, so as to leave only narrow strips or isolated fragments, as may be seen in some of the small bays on the ocean to the west of the polyzoal limestone outcrop (Fig. 2) ; and also between Honeysuckle Point and Point Leo, and at Coles' Beach, all in Western Port Bay. Where complete removal has occurred, the ultimate platform replaces the normal platform, in some instances right to the shore. A fine example of numerous channels cut through an extensive normal platform occurs on the ocean coast in front of the polyzoal limestone outcrop just mentioned. The normal platform often has a decided sloping fall parallel to the coast-line from a headland to a bay as, e.g., in Shoreham Bay just south of Shoreham.

The normal platform varies much in width, that is to say, the length across the platform at right angles to the shore. It is wider in the bay than in the ocean. Thus of fifteen measurements or estimated measurements in the bay the average width is about seven chains. Of nine in the ocean the average width is about five chains. In the bay, the platform at Honeysuckle Point attains a width of about seventeen chains which is about the width of the

platform in the ocean in front of the polyzoal limestone outcrop. This width, however, is abnormal. (It should be mentioned that none of the measurements was made in pronounced indentations, where the platform is usually much reduced in width or altogether removed by marine erosion, as already pointed out).



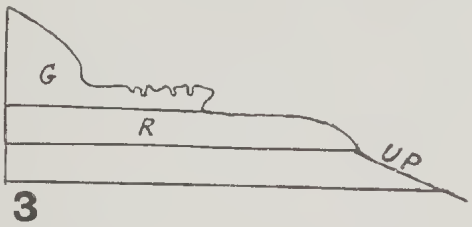


Fig. 2. Diagrammatic plan showing the removal of the normal platform in small bays with the formation of the ultimate platform. N.P. Normal platform. U.P. Ultimate platform. S. A small Stack. About one and a half miles east of the mouth of Stockyard Creek on the ocean.

Fig. 3. Section showing an irregular-surfaced platform cut in the grey (G) rock at the foot of a cliff and a lower smoother platform cut two to three feet below the upper one along the junction of the grey and red (R) rocks. Both platforms may be regarded as two phases of the normal platform passing down into the ultimate platform (UP). Between the pier and the southern end of West Head.

The outer, seaward edge of the normal platform is, as a rule, frayed and uneven, in places very much so, on account of the varying resistance of its component parts to marine erosion.

The platform is composed either of the tough grey basalt, subsequently referred to as ' the grey rock ', or of the red or brown pyroclastic rocks, decomposed basalt or the peculiar red clay already referred to, subsequently collectively referred to as ' the red rock', or partly of one type and partly of the other. Both forms have pronounced joints. An excellent illustration of the two types of platform, in this case the red in front of and lower than the grey, occurs in the bay a short distance south of the pier as shown by Fig. 3. A similar example is on the eastern side of West Head towards the northern end of that feature, where a smooth-surfaced grey platform abuts the cliffs, and a similar red one abuts the seaward edge of the grey platform eighteen inches to three feet below the level of the latter. Thus within certain limits the normal platform occurs at different levels.

In places there are areas of various size sunk, as it were, for a depth of a few inches to two or more feet beneath the level of and entirely surrounded by the normal platform. An example occurs at the foot of a headland on the ocean about midway between the mouths of Double and Stockyard Creeks, where a lower red platform is surrounded by the walls of the hard upper grey platform. More details are given in the section discussing the origin of the normal platform.

Whilst the surfaces of the platforms are as a rule almost horizontal (although some have a distinct slope seaward of a few degrees) and are, on the whole, fairly smooth, roughened surfaces occur on some of the hard grey platforms ; and, in places, ribs of the same kind of rock occur separated from one another by erosion channels. The softer red platforms are generally very smooth over

both large and small areas, and where irregularities occur they are chiefly owing to patches of the grey rock in the platform.

Where iron oxide has formed along the joint planes of the rocks, as at the ocean to the west of West Head and, in the bay, at Point Leo, its great erosive resistance produces a somewhat jagged surface.

In addition to the minor irregularities previously mentioned, residuals, a few square feet in area, from eighteen inches to eight feet high and of both types of rocks, are found on the normal platform. A comparatively large one occurs just to the north of Shoreham. At Coles' Beach in the bay, some basalt dykes traverse the red rock platform and stand three to four feet above it.

Small stacks, distinguished by their greater size from the residuals just mentioned and composed chiefly of the grey rock, are displayed on the ocean coast and are undergoing removal by the sea, an interesting point being that at some stacks the attack is greater on their landward than on their seaward side, owing mostly to a soft band outcropping on the landward side (Plate VII, Fig. 1). High-level platforms, a few square yards in area, of great smoothness, have been cut by the sea on some stacks in the grey rock.

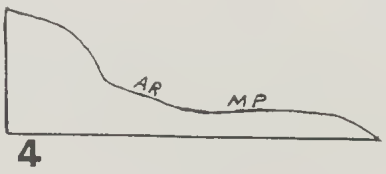
The surface of a red platform between Boyd's Point and Manton's Creek in the bay is irregularly and shallowly pitted, the pits being a few inches only in diameter. Shallow rock holes or basins containing water when the tide recedes and the bottoms of which are often covered by sand and growing seaweeds, are characteristic of some platforms.

The normal platform passes seaward into the ultimate platform either by a gentle slope or a sharp drop, whence the sea rapidly deepens. Similarly in bays where the normal platform has been replaced by the ultimate platform the junction may be sharp or gradual. Ramparts as defined by Wentworth (1938) do not exist on the normal platform except to a very minor extent.

Shingle, except in some hollows, is generally absent from the normal platform, but there are some small accumulations in the bay north of the pier and some pronounced ones on the eastern side of West Head and on the extensive broken platform in front of the polyzoal limestone at the ocean. The bands are in places crescentic in outline on one or more of their sides. Sand and marine organic growths are found on some normal platforms.

Abrasion Ramps

The abrasion ramp (Wentworth, 1938) is up to about half a chain wide, but just south of East Creek, in Western Port Bay, it is about one chain wide, an unusual width. Its angle of slope is from 3° to 10°. It practically universally occurs at the foot of the cliffs and forms portion of the normal platform (Fig. 4). It can be traced, in places, where covered by heavy shingle. It is generally smooth but where the rocks are hard there may be minor irregularities as, for example, on the eastern side of West Head.



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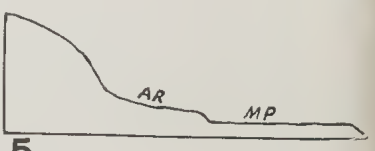

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Fig. 4. Section showing the general form of the abrasion ramp (A.R.) at the foot of the cliff and its relation to the main portion (M.P.) of the normal platform.

Fig. 5. Section showing an unusual break of about 18 inches vertically between the abrasion ramp (A.R.) at the foot of the cliff and the main portion (M.P.) of the normal platform. East of the mouth of Double Creek on the ocean.

Where the normal platform has been destroyed, the abrasion ramp forms the most landward portion of the ultimate platform, and so it is simply part of the general seaward slope of that platform ; whereas in the case of the normal platform it is more prominent owing usually to the change of slope at the seaward boundary of the ramp. In some cases, e.g., to the east of the mouth of Double Creek, on the ocean, there is a distinct step up to eighteen inches in height between the outer horizontal portion of the platform and the ramp. (Fig. 5). The abrasion ramp may be absent in front of some of the high-level platforms.

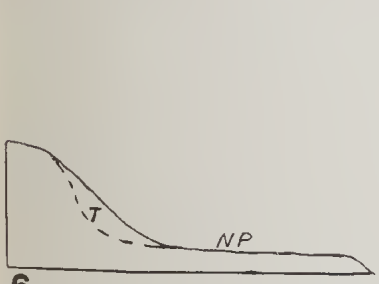
The Resurrected Platforms

In some places, as at Boyd's Point, the abrasion ramp of the normal platform passes beneath the talus covering the face of the cliff and so there is a fossil platform. Parts are now being uncovered by the removal of the talus by the action of the sea, and so the fossil platform changes to a resurrected one. The talus is probably a few feet thick only (Fig. 6).

The High-Level Platforms and Associated Shelves

There are numerous platforms which are not covered by every high tide up to about a chain wide and which run parallel to the coast for varying distances. They are from two to six feet or more above the normal platform, occur chiefly at the headlands and are much more pronounced on the ocean coast than on the bay one. It cannot be said that there is one definite level, for they occur at different heights, and there may be two or three platforms or steps one above each other. In addition to these distinct benches, higher up the cliff face are one or more narrow shelves, up to about four feet wide, generally free from talus and vegetation. These may attain a height of fourteen feet above the normal platform, to which level the waves and sea spray at times reach. A marine gasteropod is found living to the same height. Above the reach of the spray are other shelves which carry talus and vegetation.

Examples of the high-level platforms and shelves occur at the ocean at the southern end of West Head (Fig. 7) and at several of the headlands west of the



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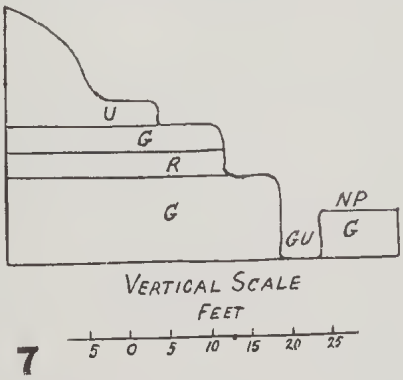

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Fig. 6. Section showing platform and cliff in course of resurrection. N.P. Normal platform. T. Talus on cliff face. The solid line is the present surface. The broken line is the former surface. Boyd's Point, Western Port Bay.

Fig. 7. Section showing a gulch in the normal platform and the formation of a high-level platform and shelves above the normal platform up the cliff face. Sea spray reaches to the highest shelf, which is 12 feet above the normal platform, and living marine mollusca are found on the shelf two feet below the top one. N.P. Normal platform. G. Grey rock. R. Red rock. GU. Gulch. U. Undetermined rock. S.E. end of West Head.

polyzoal limestone outcrop. Further examples are : (i) On the eastern side of West Head where shingle is banked against the cliff face, but otherwise this particular high-level platform is free from debris of any kind. The shingle is at the same level as that at the head of the beach on each side of the platform ; (ii) At the small stack in the ocean about half a mile to the west of the mouth of Double Creek where two irregular curving platforms a few square yards in area occur, one about two feet six inches above the other, and the latter about six feet above the normal platform (Plate VII, Fig. 2). Both are cut in the grey rock and both have very level surfaces. Further examples of the high-level platform occur immediately to the south of Shoreham at several headlands where the platform drops sharply on three sides to the normal platform.

The surfaces of the high-level platforms are horizontal or nearly so, though Plate V, Fig. 2 illustrates an exception. They are usually composed of the grey rock but red high-level platforms occur. Shingle is found occasionally on the high-level platforms about four feet above the normal platform as at two points on the eastern side of West Head but as a rule these platforms are free from debris of any kind.

The Ultimate Platform

This is the platform of which very little can be seen even at low tide; for it is being formed below the level of the normal platform by the destruction of the latter. In some instances the ultimate platform originates without the intervention of the normal platform. The seaward portion of the latter falls either sharply or gently to the ultimate platform which extends seaward with apparently a steady fall in that direction. The tide never falls low enough to permit this lowest platform to be seen for more than a few square yards near the shore in places where the higher platforms have been removed or have never existed. The seaward face of the normal platform is being removed by the ' quarrying ' action of the waves and if such removal is faster than the retreat of the cliffs at the back of the normal platform, the latter will ultimately disappear. This has happened in numerous small bays where the ultimate platform, mostly covered with sand, shingle and organic growths, falls with a pronounced slope seaward, with the remains of the normal platform projecting from the headlands at a higher level. Hence, in some bays, only the abrasion ramp, which is common to both the normal and ultimate platforms, is seen.

The ultimate platform is the wave-cut platform figured in nearly every text book of geology and geomorphology as the normal result of marine abrasion, thus overlooking the possibility of the normal platform being formed at the same time as or prior to a particular portion of the ultimate platform. A clear recognition of the normal platform apart from the ultimate platform is contained in C. A. Cotton's recent volume on geomorphology although he does not use the terminology of the writer.

As the sea encroaches on the land, the surface of the ultimate platform is no doubt steadily lowered by erosion and consequently becomes covered by deepening water unless sedimentation takes place which, however, for a time, wave or current action may prevent or retard. Dredging and soundings are required to ascertain the depth and angle of slope of the platform and the nature and thickness of such of the deposits as rest upon its surface.

Rock Fans

These features are restricted almost entirely to the bay coast, the conditions along the ocean favouring more the production of definite steps between the normal and high-level platforms or between different portions of the normal platform. A coastal rock fan may be defined as a portion of the normal platform

or a combination of a high-level platform with the normal platform, which projects from the coast-line as a very flat half-cone or fan, the base of the fan being identical with a portion of the coast-line. The slopes of the fan vary from 3° to 10° but such steady slopes are not always maintained. They may rise steadily to the highest portion of the fan at the coast-line either without any definite break or by one or more steps from a few inches to perhaps two feet in height. The outer (seaward) boundaries of the fan are determined by the usually definite change from the angle of slope noted to an approximately flat surface, although in some fans ' cliffs ', a foot or two in height, have formed at the main seaward edge. Some fans are convex upwards in all directions but this is apparently not true in every case. The result is that small bays of varying length and depth are formed on either side. The bottoms of these bays are parts either of the normal or the ultimate platform.

There appears to be a rough uniformity in the dimensions of a fan. Thus the distance from the middle of the base of the fan in all directions is frequently the same, the average length being from one to two chains, but some fans reach three to four chains in various directions. The intervening bays are small or comparatively large according to whether the fans are closely or widely spaced. There is no rule as to spacing of the fans, for as will be shown below, the occurrence of the fan is primarily due to the lithological character and geological structure of the rocks, and these features vary in space indefinitely. The rock fans are usually or most prominently at the foot of the headlands, but they may occur independently of the latter. Examples of the fans occur at Boyd's Point, to the south of Shoreham, and between Point Leo and Coles' Beach all in Western Port Bay.

Origin of the Platforms and Related Features

Governing Structural and Lithological Factors

These factors, both on the ocean and the bay coasts are :

(i) The occurrence of distinct lava flows immediately following one another or separated by a bed or several successive beds of pyroclastic rocks or the peculiar red clay previously referred to.

(ii) The great variation in the ' hardness ' and ' softness ' of the different rock groups. In the lower portions of the cliffs a basalt flow consists, in many places, of a practically fresh, tough, dense, dark grey rock ; in a flow immediately above or below, the rocks may be moderately or much decomposed. The pyroclastic rocks, from their original nature, and the red clay are much less resistant to erosion than the basalt. This resistance is further lowered by the decomposition which has in some instances taken place in the pyroclastic rocks since their deposition.

(iii) The approximate horizontality of many of the upper and lower surfaces of the various bands of rock. Those surfaces are, however, in places either gently or steeply inclined but a steep ' dip ' is not common, and on account of the large number of practically horizontal surfaces there is little truncation of the beds.

(iv) The almost universal traversing of the basalt by vertical or nearly vertical polygonal joints resulting in columnar structure. The polygons are frequently up to three feet wide, less frequently two feet to eighteen inches, and, rarely, six to nine inches. Spheroids coincident usually with the width of the columns occur, and within the larger spheroids numerous smaller ones are found. Many columns are also traversed by innumerable short irregular joints and in others a platy structure is developed which varies from 0° to

about 40° from the horizontal. The platy structure is well seen at a small coastal projection on the eastern side of West Head.

The pyroclastic rocks are also in places strongly jointed but much more irregularly than the basalt. The joints dip at almost all angles between the vertical and the horizontal. Long prominent joints have minor joints running off in various directions and for varying distances.

(v) The varying thickness of the bands of both classes of volcanic rocks. This variation is from a foot to thirty or forty feet but usually does not exceed twenty feet. An individual band may in a short distance thicken, thin, or altogether die out, resulting in places in a lenticular character ; and so many of the planes between the different rock masses are undulatory.

Mode of Formation

The Normal Platform

The normal platform lies between tide marks, and at the foot of the cliffs the abrasion ramp is being extended landward by wave attack. The ramp is generally smooth-surfaced whether the rocks composing it be red or grey, that is whether ' soft ' or ' hard '. The extension of the platform is also going on around stacks by the waves undercutting the stacks. These facts indicate that the present landward extension of the platforms is due to wave planation, using that term in its broadest sense, and there is nothing to suggest that the whole platform was not originally formed in the same way.

The alternation of grey (hard) with red (soft) rocks has an important bearing on the formation of the platforms and related features. Where a grey band is overlain by a red band, the latter is rapidly removed by wave attack leaving a platform of grey rock. That platform can be removed, although more slowly than the red one, by the ' quarrying ' action of the waves on the exposed more or less vertical face of the band ; and if there is another red band below, a red platform may be formed, as may be seen at a headland on the ocean a little to the west of the mouth of Double Creek and on the eastern side of West Head. A fine example of the removal of a grey platform leaving a red one below occurs between West Head and Boyd's Point (Fig. 8). A more advanced stage is the almost entire removal of the grey rock (Fig. 9).

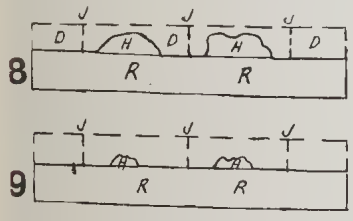
A further example occurs just to the south of Boyd's Point at two small residuals (Plate VI, Fig. 2), where erosion has cut a platform in the red rock two feet below its junction with the overlying grey band.

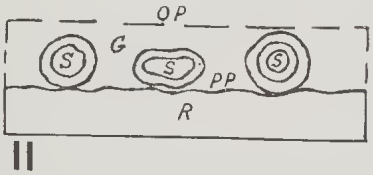
Where a red band occurs between two grey ones, the upper grey band and the red band may be simultaneously removed, with the formation of a nip in the red band and a platform along the upper surface of the lower grey band which in turn may be reduced to a lower level, as shown on the eastern side of West Head (Fig. 10). Where a spheroidal grey band overlies a red band, a red platform may result with weathered out spheroids up to two feet or more in diameter of the grey rock resting on it, as may be seen between the mouth of Stony Creek and Honeysuckle Point (Fig. 11) and about 100 yards north of the pier in Western Port Bay (Plate VI, Fig. 3). Between Boyd's Point and Manton's Creek, two distinct red bands are seen, one overlying the other. A platform has been cut along the line of separation of the bands and that platform is now being destroyed by the ' quarrying ' action of the waves on the lower band. The same features occur at the ocean to the west of Double Creek (Fig. 12). Thus there are distinct steps downward as one traverses the platform seaward. With the destruction of the normal platform, the ultimate platform extends itself landward.

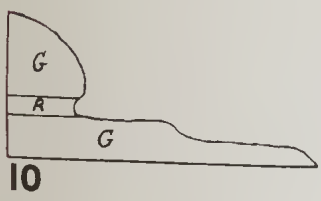
Sunken areas within the normal platform have been referred to in the general description of the platform. The waves work down a joint plane of

the grey rock and may find a red rock below. The softness of the latter enables the grey polygons to be undermined and they then topple over, and are gradually broken up and removed by the waves. It is remarkable that a grey upper band may be removed by lateral erosion at its base after the vertical joints have been widened by downward erosion, leaving the soft red band as the surface, substantially or little eroded, of another lower platform. The area attacked will spread and if, as in places occurs, several of such areas are being formed at the same time, serious inroads are made in the surface of the normal platform. Two or more areas may coalesce and so a wide platform may ultimately develop excavated out of and surrounded by the normal platform. If the deepening continues, the lower platform will eventually become part of the ultimate platform.

The differences in height between successive platforms or shelves, and the slight rise or fall of the surfaces of some of the platforms are owing, mainly, to the differences of thickness of the component rock masses, and to the undulatory







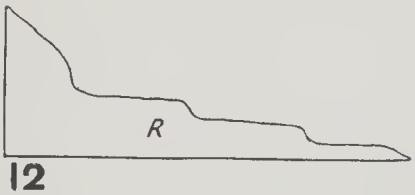


Fig. 8. Section showing the remains of a platform of grey rock after the removal, on each side of joint planes, of decomposed portions of that rock. The surface of the original platform is indicated by the broken horizontal line. H. Hard grey rock. D. Decomposed grey rock removed. R. Red rock. J. Joints. About 200 yards north of the pier. See also Fig. 12.

Fig. 9. The same section as Fig. 8 showing the further removal of portions of the grey rock. The lower red rock (R) where not protected by the grey rock remnants (H) has also been removed to a varying depth up to 18 inches. J. Joints.

Fig. 10. Section showing two platforms, the lower one cut in the grey (G) rock and the upper one (about four feet above the lower one) cut along the junction of the grey and red (R) rocks, with a pronounced nip at the foot of the cliff in the red rock which is about four feet thick. Grey rock lies above the red rock. The lower platform passes downward into the ultimate platform. Between the pier and the southern end of West Head.

Fig. 11. Section showing the spheroidal remains (S) (the spheroids being up to about two feet in diameter) of an old grey platform (OP) resting on the present red platform (PP). The grey platform was originally about three feet above the red platform. The red platform has doubtless been lowered by erosion. G Grey rock. R. Red rock. North of Stony Creek Western Port Bay.

Fig. 12. Section showing three platforms, all in the red rock (R) rising one above another, at vertical intervals of about one foot, to the base of the cliff, and, seaward, dropping to the ultimate platform. A little west of the mouth of Double Creek on the ocean.

surfaces of the latter ; for it is along the junction of these masses that the platforms or shelves are most easily cut.

As stated in the portion describing the coast-line, the height of the cliffs of the ocean is from 100 to 200 feet, whilst those of the bay are from 50 to 100 feet high, and at some of the most prominent headlands, e.g. Point Leo and Honeysuckle Point, the height is only about 50 feet. Therefore, other things being equal, the retreat of the ocean cliffs would be slower than those of the bay, in consequence of the greater amount of material to be removed by the waves from the former. But other things are not equal, one important difference being the much greater strength of the waves on the ocean front, due to the long fetch there as compared with the fetch in the bay. Probably the rocks of the ocean coast are tougher than those of the bay by reason of the surface of the country adjoining the ocean coast being considerably higher than the surface of the country adjoining the bay coast with the result that the lower limit of decomposition is nearer sea-level in the bay rocks than in the ocean rocks. Hence both height and strength of the ocean rocks are greater than in the bay ones ; and therefore, despite the greater strength of the waves on the ocean coast, the retreat of the cliffs and of the seaward edge of the platform there is probably slower than on the bay coast.

The faster retreat of the bay cliffs would also account for the mature coast-line of the bay as contrasted with that of the ocean. For the same reason, if we omit for the moment the rate of recession of the seaward edges of both ocean and bay platforms, the bay normal platform, as is the case, should be wider than the ocean normal platform. The rate of recession of the seaward edges of the platforms must, however, be taken into account, and it would seem that at the present time or in the immediately preceding past, the cliffs of the bay platform have retreated faster than the seaward edge of that platform despite the fact that much more material had to be removed at the landward edge of the platform, owing to the height of the cliffs, than at its seaward edge. The explanation probably is that at the seaward edge the rocks are much harder than those composing the cliffs. No definite rule can, however, be laid down since the rocks are not homogeneous. Doubtless the same factors operate on the ocean coast, although in not so pronounced a fashion.

Structural control is much the same in the ocean and bay rocks so that apparently it does not have any substantial bearing on the rate of retreat of either the cliffs or the seaward edges of the platforms.

Valleys reaching the ocean enable marine erosion to proceed at the mouths of the valleys at an accelerated pace in consequence of the removal of so much of the cliffs by stream erosion. At Flinders, valleys join both the ocean and bay coasts in the embayments, and the spacing and size of such valleys are much the same on both coasts, so that neither coast appears to gain an advantage over the other by reason of their occurrence.

As a platform widens the waves lose much of their erosive power. Consequently the retreat of the cliffs will slow down and, as a coast-line becomes more mature, the headlands are wider-spaced and the intervening long bays develop extensive beaches, which in turn yield the sand that the wind seizes and builds into dunes. In this way, large portions of the coast are, temporarily at least, protected from wave attack. This has happened on the bay coast, but as the headlands are further reduced another attack will be made on the protected areas until they reach a stage at which protection will begin again.

It must also be borne in mind that there may be changes in the shore currents, and that erosion or deposition at one point may change the strength or method of attack at another point and so, perhaps, bring about an increase or a decrease of erosion or deposition at that second point. That is exemplified

in the changes wrought in a coast-line by the erection of walls and groynes to retard crosion and even by the construction of piers.

The Abrasion Ramps and Resurrected Platforms

The abrasion ramps are difficult to account for and the writer knows of no really satisfactory explanation of why that portion of the normal platform should have a definite slope. They are very widespread, almost universal features of the Flinders coast. As the cliffs recede, the ramp migrates landward. At the same time it is being reduced seaward by marine erosion to the level of the main portion of the platform. The resurrected platforms, since they appear to be merely the buried extensions of the present abrasion ramps, now in course of exposure again, call for no further statement.

The High-Level Platforms and Associated Shelves

The high-level platforms and the shelves immediately above them (Fig. 7) are being cut by wave planation assisted no doubt by the crumbling of the soft rocks, owing to their alternate wetting and drying. The higher of these shelves, which are free from talus and vegetation, are apparently the result of spray crosion combined with the work of the atmospheric agents in the manner described in the writer's paper on the platforms of the Sydney district (1939).

The occurrence of high-level platforms at the foot of headlands is generally owing to the outcrop of rocks more resistant than those on each side of the headland, the undulating surfaces of the rock bands favouring this difference in erosion resistance.

The Ultimate Platform

This platform has been described and its origin sufficiently indicated in the general description of the platforms so that nothing further need to be said here.

The Rock Fans

These appear to be chiefly owing to the undulating surfaces of the alternating red and grey rocks by means of which resistant layers project at certain points along the bay coast and give rise to bays cut in places in softer rocks. This disposition of sea and land favours the trimming into shape of the fan, since the waves as they pass into the bay on each side of the projection wheel round to a direction at an acute angle or practically parallel to the coast-line, and so they pass on to the fan which they gently abrade, thus tending to reduce initial irregularities of the surface. At the front of the fan the sea can make a stronger attack and hence a small cliff or a series of low steps may result, but not in all instances, the frontal slope in some fans being gradual.

The Modification of the Normal Platform Surface

Having described the various platforms and associated phenomena and indicated in a general way their origin it will be of advantage to consider in some detail the destructive agencies at work on those features, the record of which should throw light on the origin of the platforms themselves. Wentworth (1938, p. 10) has emphasized the necessity for such observations. Since the normal platform is the largest and most accessible and is usually covered and uncovered by the sea every day, the remarks following will apply mainly to that platform, but it must be clearly understood that the formation of the platform in the first place is, in the writer's opinion, due to the direct attack of the waves on the base of the cliffs.

If a platform be composed of grey rock its surface may be modified and at the same time be kept generally smooth by wave planation. A commoner

method of reduction is the cutting by the sea of channels along the vertical or nearly vertical joints to varying depths up to three or four feet, when lateral abrasion rounds off and gradually removes the various polygons and forms another lower platform, composed of either the grey or the red rock, but pending the formation of the lower platform, the original platform may become much roughened.

The grey rock is in places decomposed along the vertical joints over an area up to 12 inches in width (Fig. 13). This fact aids the abrasional attack very much.

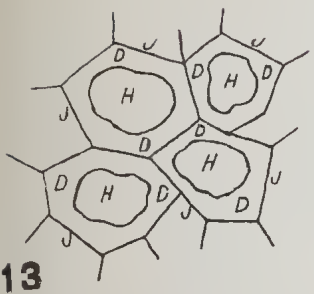
A further contributory factor to the reduction of the grey platform is the occurrence of small irregular joints a few inches apart within each polygon. Water soaks into the rock along these joints with resulting wetting to some extent. The rock dries out, wholly or partly, at low tide, and this alternate wetting and drying loosens the rock along the small joint planes, as well as generally weakening its cohesion as a whole. The waves, passing over the rock surface, may break off and remove fragments usually up to two to three inches (although some are less and some up to eight or nine inches) in size, as may be seen on a platform a short distance north of Manton's Creek in Western Port Bay. These are in places converted into shingle by the action of the sea and in the course of this change the rock fragments must rasp the platform. Just north of Shoreham are some polygons of hard basalt rising above the platform. A close-set spheroidal system is within each polygon so that rounded fragments up to about 3 inches in diameter break away and provide an almost ready-made shingle. Pronounced horizontal joints or the occurrence of a platy structure in the grey rock by aiding decomposition and disintegration will also aid in the reduction of the platform (Plate VII, Fig. 3).

If a band of red rock underlie the grey and the former is able to be attacked by the sea, undermining of the grey rock occurs, resulting in its consequent rapid separation from the parent mass. This has been illustrated in the section dealing with the mode of formation of the platforms.

If a platform be composed of red rock, wave planation of its surface would seem to be the chief reducing factor, for the rock is soft and even-surfaced platforms are easily cut in soft rock. Undermining, where still softer rocks underlie the platform, will also operate.

A second method of the lowering of a red platform is by the formation of small irregular rock holes or basins in the platform. These have already been referred to. These basins are from a few inches to about two feet deep, from a foot or two to about eight feet or more in length and are narrow in proportion to their length. The basins originate mainly along the numerous irregular joints which traverse the platform, which run in all directions, which are traceable for yards or for inches, and which unite at various angles (Fig. 14). The sea by direct abrasion along these lines erodes channels a few inches wide and deep. They gradually widen and deepen and if there are several intersecting joints, erosion around the intersection is greater than elsewhere. They frequently retain at the surface an angular outline. Exactly how the initial furrows are widened and deepened it is difficult to say. The shapes of the basins and the lack of smoothness of their sides preclude pot-hole erosion, although there are in some basins a few rounded pebbles. Instead there is the process which may be defined as ' sapping ' which is now described.

The tide, on its retreat, leaves the basins full of water (rock pools) which soaks into the surrounding rock, the edges of which, at the surface of the platform, can clearly be seen to be softened by this soaking, with the result that fragments at and near the top are easily broken off, and so the basins become widened. If the joint planes are inclined away from the vertical and



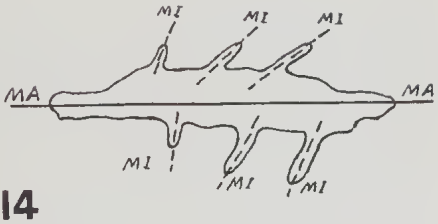


Fig. 13. Diagrammatic plan of portion of the grey platform in course of destruction. J. Vertical joint planes. H. Hard grey rock. D. Bands of decomposed grey rock two to 12 inches wide adjacent to the joint planes and now removed by marine erosion. About 200 yards north of the pier. See also Figs. 8 and 9.

Fig. 14. Diagrammatic plan showing the development of a rock hole on the normal platform along a major joint (MA) and the influence of minor joints (MI) on such development. Between Stony Creek and Honeysuckle Point, Western Port Bay.

inward into the rock the process is quickened by the undermining and collapse of the undermined portions.

In addition to the sapping, with an incoming tide and with a fairly strong sea, there must be a certain amount of scouring out of the basins, despite the absence of true pot holes, which thus become widened and deepened. It is to be noted, however, that in many basins, the sides and bottom, as well as the included boulders, are covered with growing seaweeds and other organic growths so that for certain periods, at least, scouring must be at a minimum.

The pool weathering of Wentworth (1938) does not appear to operate on the normal platform to any extent since ramparts are almost wholly absent.

In both classes of rocks, the surface of a platform as a whole is exposed to wetting and part drying, and thus a general disintegration may take place, the products of which are swept away by the next incoming tide. This process may be fairly rapid with the soft rocks and doubtless very slow with the hard ones.

True potholes scantily occur in the grey rocks but are almost wholly absent from the red ones.

The platforms are exposed twice a day for some hours so that when rain falls on them disintegration may take place.

It will thus be seen that the general lowering of either the grey or the red platform is owing to many factors of which erosion along joints is one of the most important.

Crystallization of salts from evaporating water on the platform has not been noticed, so apparently that form of disintegration of the rock surface does not occur.

Further reduction of a platform may be prevented temporarily where one portion has become eroded to a slightly lower depth than the main portions, since the hollow may become filled with shingle or sand, as may be seen in Western Port Bay between the first two headlands north of the pier.

The general result of the above described processes will be a roughening of the platforms, as Douglas Johnson (1938) has suggested in regard to certain processes of secondary weathering of wave-cut platforms put forward by Bartrum and Turner (1928, p. 271).

The Platforms in Relation to the Question of Recent Emergence

An examination of the platforms and shelves does not yield any definite evidence of a recent emergence of the shoreline to the extent of a few feet

vertically. The sea is now cutting benches to a height of at least ten feet above the normal platform.

It is, of course, possible that the high level platform and the shelves above it (or some of them) were cut at a level lower relatively to sea-level than at present, but that appears to be a possibility difficult of proof and consequently those features throw no light on the matter. The writer has not looked specially for other evidence of emergence, such as sedimentary deposits, but no such evidence has come under his notice, although T. S. Hall (1902) has suggested that certain deposits are evidence of recent emergence to the extent of at least five feet. Even if such evidence be found, it will be difficult to correlate it with any of the platform features, since they occur at different levels. Resurrected platforms appear to be uncovered continuations of present abrasion ramps, so that they do not indicate recent elevation. They and the vegetated 'fossil' cliffs are best accounted for by assuming that marine abrasion in certain areas temporarily ceased or slowed down, during which period the atmospheric waste from the cliffs accumulated, thereby burying the face of the cliffs and the immediate portions of the abrasion ramps at their foot. The slowing down of marine abrasion may be due to a change in the direction or strength of the prevailing winds or in the currents of the sea or to or combined with the deposition of sand (blown or water-borne) and shingle deposits. Some of the fossil cliffs are now again being eroded.

The normal platforms appear to have been cut with sea-level as at present. If so, then there has been a fairly lengthy stillstand of the land, with much cutting back of the cliffs and doubtless destruction of those easily removed deposits, such as raised beaches, if they ever existed; but allowing for extensive erosion, one would expect to find some convincing evidence of recent emergence.

If there has been recent emergence then the normal platform cut prior to emergence must have been almost totally destroyed during the period of the formation of the present normal platform. Similarly with regard to the ultimate platform if any portions of that platform had prior to emergence reached the shore without a normal platform intervening, those portions have been destroyed.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